Utilization of Sugarcane Bagasse Fibers for the Manufacture of Bio-Composite Panel

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ABSTRACT

Agricultural waste such as sugarcane bagasse is abundant in Malaysia and at present is mainly used as combustible material for energy supply in the sugar factory. This study was conducted with the aim to investigate the possibility of manufacturing bio- composite panel from sugarcane bagasse at three different density levels namely(450 kgm^{-3}, 550 kgm^{-3} and 650 kgm^{-3}, two amount of resin contents such as 10 and 12% and with the addition of 1% wax or without wax addition. The panels produced were tested for mechanical properties such as Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) and physical properties namely water absorption (WA) and thickness swelling (TS) conforming to the European Standards (EN 310). The results revealed that those panels with board density 650 kgm^{-3} gave superior mechanical strength (MOE value of 1152.06 MPa) and board density of 450 kgm^{-3} (MOE value of 545.15MPa). An increase in the amount of resin content from 10% and 12% resulted in the increment of MOE value from 1082 MPa to 1114 MPa. The addition of 1% wax helped to improve the water absorption (decreasing from 52% to 42%) and thickness swelling (decreasing from 27% to 24%) of the bio- composite panels. Thus, it can be concluded from the above findings that bio-composite panel can be successfully manufactured from sugarcane bagasse as the potential source of raw material from agriculture waste.

Keywords: *sugarcane bagasse, mechanical properties, resin content, board density, wax addition*

Introduction

Sugarcane or Saccharum is one of the most natural fibers that are produced with a worldwide annual production of 1170 million metric tons in 2005 (FAO Statistics, 2006). Bagasse consists of approximately 46% cellulose, 24.5% hemicellulose, 19.95% lignin, 3.5% fat and waxes, 2.4% ash, 2.0% silica and other elements (Anding, 1978). Bagasse is the solid lignocellulosic residue left after extraction of juice from the sugar cane stalk. Bagasse is used as combustible materials for energy supply in sugarcane factories as in thermal power station, in pulp and paper industries and for fiber board materials.

Usually in the manufacturing of composites such as furniture, particleboard and etc, wood is used because of their good properties but, nowadays using wood had some problems. Wood is hard to get and the price is high. This is because the plants take time to grow and large space is needed to plant them. Using wood, the production cost is also high.

Wood the wood getting scarce, the manufactures in wood-based industries need to find out the suppliers from other countries. Consequently, manufactures need to spend a lot of money to import wood from other countries for their production. The availability of sugarcane bagasse is abundant and easy to obtain. According to FAO statistics, 2006, found that sugarcane bagasse amounted with a worldwide annual production of 1170 million metric tones in 2005. In Malaysia production of bagasse was quite large in year 2005 which is 260,800 tonnes (Energy Statistics Database / United Nations Statistics Division).

Abundance of sugarcane bagasse in Malaysia happens because the usage of sugarcane fiber is not commonly to be commercialized especially in manufacturing composite material. The increasing sugarcane dregs residues, brings both environmental and surrounding problems to mankind. On the other hand, the use of non wood fibers provides the balance between supply and demand (Nemli and Kalaycioglu, 2006).

The aim of this research project is to study the mechanical properties (MOR and MOE) and physical properties (water absorption and thickness swelling) of the bagasse panel at three density levels (450kg/m^3, 550kg/m^3, 650 kg/m^3), two types of resin content (10% and 12%) and with or without wax (1%) addition.

Materials and Methods

The sugarcane bagasse is milled by using hammer mill to get into small particles. The particles were screened to separated fiber from the parenchyma. The fibers in 2 mm are used and oven dried about 3% moisture content. Urea Formaldehyde from Malayan Adhesive and Chemicals (MAC) at Shah Alam, Malaysia are used as binder and wax with 60% solid content obtained from local wood particleboard manufacturer.

The densities for the particleboard were 450 kg/m^3, 550 kg/m^3 and 650 kg/m^3. The board was produced conducted by using different resin (10% and 12%) and wax content (0% and 1%) to measure their effected properties of panel. The panel dimension was 34 cm x 34 cm x 0.6 cm. The wax and resin were sprayed by compressed air and blended with bagasse using adhesive mixer. The blended particles were manually formed by hand forming and hot pressed under 165°C with pressure (1800 psi) for 12 minutes.

Results and Discussion

Panel with density 650 kg/m^3 gave superior properties than 450 kg/m^3 and 550 kg/m^3 board. Board produced with minimum resin content 10%, were able to meet minimum strength than 12% resin content. Board having 12% resin content and 650 kg/m^3 density were observed to possess the highest value of MOR (10.69MPa) and MOE (1634.11MPa). Introduction of wax helped to improve the water absorption of bagasse panel. Board of 650 kg/m^3 with 1% of wax gave better WA and TS compared to same board density without wax. The properties of bagasse panel are shown in Table 2.

Table 2. Mechanical and physical properties of bagasse panel

RC (%)	Wax (%)	Density (kgm^{-3})	MOR (MPa)	MOE (MPa)	WA (%)	TS (%)
10	0	450	4.20	582.10	70.28	23.88
10	0	550	6.56	1185.42	56.69	28.53
10	0	650	10.11	1569.42	43.25	27.49
10	1	450	3.27	467.16	57.43	21.98
10	1	550	7.30	1120.08	41.02	24.47
10	1	650	9.95	1564.98	30.47	23.48
12	0	450	4.02	566.74	65.91	24.61
12	0	550	8.54	1187.16	39.73	24.55
12	0	650	10.69	1634.11	36.11	30.22
12	1	450	3.73	564.60	54.07	24.07
12	1	550	6.91	1115.59	36.07	24.40
12	1	650	9.55	1614.04	29.25	26.15

Note: RC- Resin Content, MOR-Modulus of Rupture, MOE-Modulus of Elasticity, WA-Water Absorption, TS- Thickness Swelling

Statistical Significance

Table 3 shows the ANOVA of resin content (RC), wax (W) and board density (DEN) on the particleboard properties. It shows that resin content has no significant effect on MOE, MOR and WA but has significant effect on TS. For wax, effect on MOE, MOR and TS were not significant while the effect on WA was significant. Board density exhibits high significant effect for MOE, MOR and WA but no significant effect for TS. The interaction of RC*W, RC*DEN, W*DEN and RC*W*RC were found to be not significant.

Table 3. Summaries of the analysis of variance (ANOVA) on the effect of resin content, wax content and board density on the mechanical and physical properties of bagasse panel.

Source	Df	MOE	MOR	WA	TS
RC	1	0.85ns	0.75ns	4.40*	1.06ns
W	1	2.87ns	1.56ns	12.64*	0.29ns
DEN	2	147.45**	267.95**	29.12**	2.00ns
RC*W	1	1.69ns	0.17ns	1.21ns	1.31ns

RC*DEN	2	0.86ns	0.22ns	0.64ns	0.19ns
W*DEN	2	0.04ns	0.22ns	0.1ns	0.76ns
RC*W*DEN	2	2.21ns	0.31ns	0.29ns	0.88ns

Note: **F- values are highly significant at p<0.01, *F-values are significant at p<0.05and ns – not significant, W-Wax content and DEN- board density.

Effect of Board Density

Figure 1 shows the effect of board density on MOE. Board density with 650 kg/m^3 give superior properties with 1595.64MPa compared to other two board density, 450 kg/m^3 (545.15MPa) and 550 kg/m^3 (1152.06MPa). Higher density of board gave high compaction to board thus increasing the strength properties. Increase board's density effected the increase of MOE and MOR. According to Zheng et al., 2007, high density board has lower porosity compared to lower density board and caused the particles and adhesives interact with each other more easily to form stronger crosslink. In figure 2, MOR increase by increasing the board density (450 kg/m^3, 3.81MPa; 550 kg/m^3, 7.33MPa and 650 kg/m^3, 10.08MPa) while WA were decreased (450 kg/m^3, 61.92%; 550 kg/m^3, 43.38% and 650 kg/m^3, 36.02%). However, increase in board density caused poor TS (Au and Zheng, 1989).

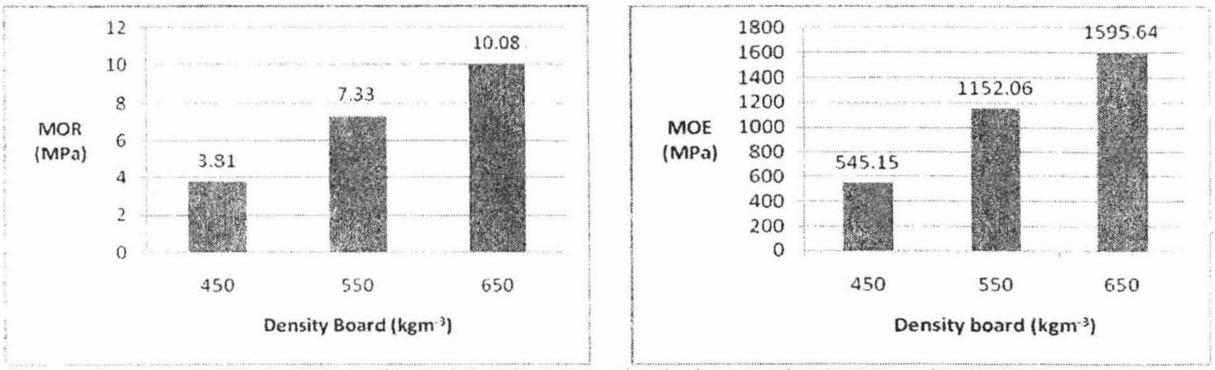

Fig. 1. Effect of board density on mechanical properties (MOR and MOE)

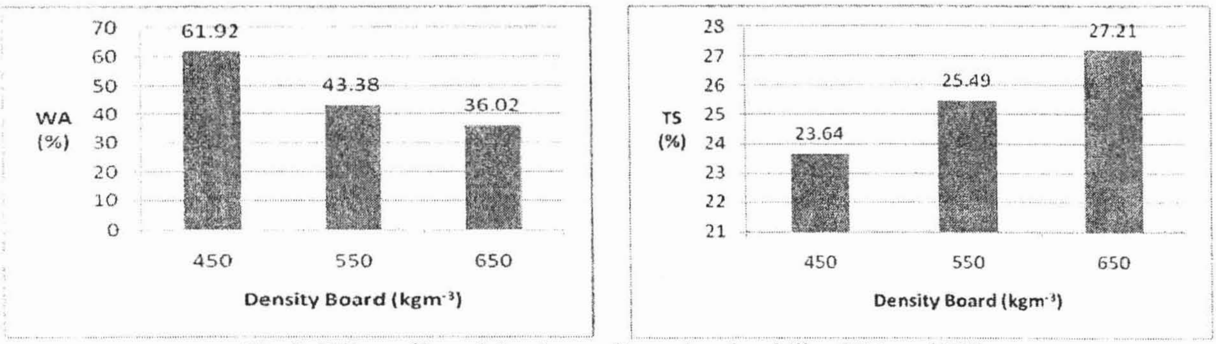

Fig. 2. Effect of board density on dimensional stability (WA and TS)

Effect of Resin Content

In general, increment of resin content decrease the WA and TS (Pan et al., 2007). Figure 3 shows resin content effect on the MOE means increase of the resin content from 10% to 12%, the values of MOE increase 1081.53MPa to 1113.71MPa respectively. Figure 4 shows MOR increase while WA decreases with increasing the resin content. High resin content caused more bonding sites and produced board with high MOE and MOR.

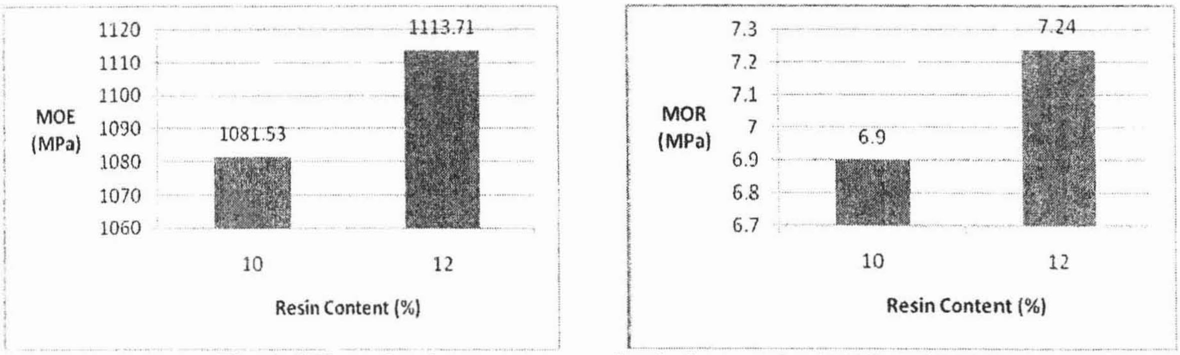

Fig. 3. Effect of resin content on mechanical properties (MOR and MOE)

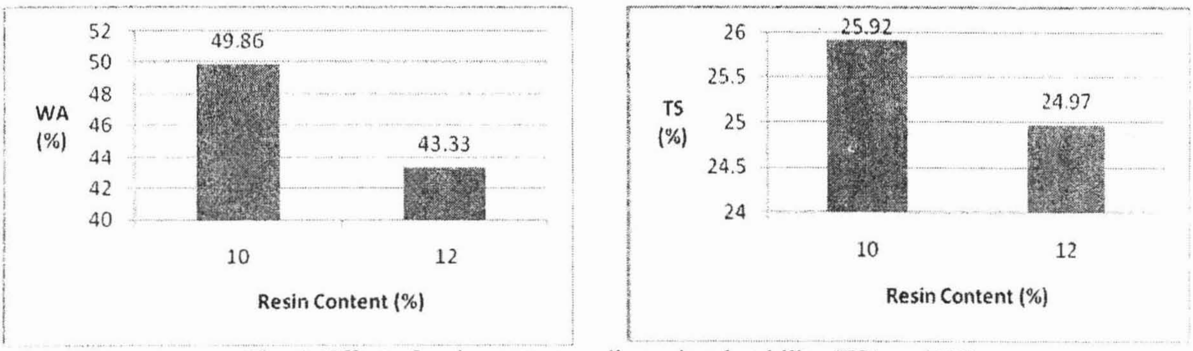

Fig. 4. Effect of resin content on dimensional stability (WA and TS)

Effect of Wax

Three different methods can be used to improve the water resistance and reduce the thickness swelling. The first method is by adding wax during the manufacturing of board, the second methods by reducing the density of particleboard (Okino et al., 2004) and the third is by using acetylating of particles (Wishered and Wilson, 1979), (Hofstrand et al., 1984). Addition 1% of wax is effective and gave no negative influence to the strength properties. Wax sizing used in moderate levels showed positive influence on long term water absorption and thickness swelling. However, addition of large amount of wax caused a decrease in MOE and MOR. By adding 1% of wax, it can decrease the WA and TS. Although small changes in WA and TS it helped to improve the water absorption inside the board. By adding 1% of wax, WA and TS decrease from 52% to 42.22% and 26.55% to 24.34% respectively.

Summary

Bagasse panel with density 650 kg/m^3 gave superior strength for MOR (10.69MPa) and MOE (1634.11MPa). Panel with wax provided less water absorption and thickness swelling because of wax's properties which helped to improve water absorption easily into panel. The WA and TS decrease from 52% to 42.22% and 26.55% to 24.34% respectively. Resin content (12%) is gave high mechanical properties compared to 10% of resin content, strength values of MOE were 1081.53MPa and 1113.71MPa while the MOR were 7.24% and 6.9% respectively.

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